HARNESSING NIAGARA.

BY GEORGE FORBES.

THERE is no class of professional men who travel so much as engineers. Their experiences are often full of interest, and at times not devoid of excitement. Yet how seldom it is that any account of these travels is found in print. This is partly due to the fact that it all seems to the principal actor to be all in the day's work, and hardly worth committing to paper. But there is also a certain pleasure in having a store of experiences to relate to one's more intimate friends, which the vulgar crowd cannot read in a book.

At the present moment I am tempted to curb this natural reticence with the object of narrating my experiences of the last few years, which I believe are unique in our profession. Our engineers are often called upon to travel in difficult countries, and to accomplish what look like impossibilities. But it is by no means an every-day occurrence for the financial men in a great country like the United States, who are not in the habit of minimizing the capabilities of their fellow-countrymen, to invite a foreigner to carry out one of the greatest works of modern times in that country. Some people say that the Americans are perhaps too much inclined to look upon their countrymen as the inventors of Electricity. It is, then, all the more surprising that the work about which the English engineer was asked to advise them was the electrical utilization of Niagara Falls. It must, however, be remembered that this work involved entirely new problems and designs, while the American electrician has less capability of evolving entirely new plans, or designing entirely new machinery, than of adapting his past experience, exactly as it stands, to new conditions. It was for this reason that one of the ablest of American engineers said in public three years ago that it was impossible to transmit the power of the Falls to Buffalo, some twenty miles, so as to make it pay ; whereas we have now established the fact that the limit of distance is to be counted by hundreds of miles.

There are two great mistakes commonly made as to Americans. One is, that they are original inventors ; the other is, that they are humorous. Neither of these propositions is true. It is true that if asked to create a knitting-machine, or a type-writer, or a reaper, they will put together well-known mechanical devices to accomplish the result. But this is designing, not inventing ; and the cause of so much work of this kind being done in America is the high price of labor, which must be replaced by steam and machinery. So with humor, with of course some brilliant exceptions, their periodical literature is filled with so-called wit, but it smells strongly of the midnight oil. I remember an incident related to me by an editor of a weekly journal. He said, " Yesterday a poor miserable man came into my office and laid before me some manuscript and said, ' O Mr. ——, I wish you would look through these jokes and pick out any you can use. I was working at them all last night, and I need money badly to bury my poor wife.' "

Invention and humor require a gift of imagination, the same gift that shows itself in poetry and letters, in music, painting, and sculpture ; and in no one of these directions has this gift of imagination been found to predominate among Americans.

I have given these reasons why it was perhaps natural to have recourse to a European to take hold of this great and entirely novel problem. Another reason is that all their electricians who may have had a wide practical experience are tied to manufacturing companies, and cannot be looked upon as independent either in thought or action ; and since it was pretty certain that any plans that might be adopted would have much of novelty in them, and would be opposed in the first place both by scientific men and by the manufacturers, it required that the man selected should have nothing to gain

or lose by the friendship or hostility of these two classes of men.

When I had finished my work at Niagara Falls the chairman (or president, as he is there called) of the company wrote me a letter, in the course of which he incidentally mentioned some of the reasons why I had been invited to carry out this work. These are given later on in this article.

Passing now from these digressions, let us come to the Falls themselves. I have no talent for pictorial description, and they are well known to a large number of my readers. I will only say that the river Niagara leaves Lake Erie at the City of Buffalo and meanders, innocently enough, through level plains for sixteen or eighteen miles, passing on the two sides of the Grand Island and then opening out into a wide lake-like expanse a mile wide, where, a mile above the Falls, the current becomes more swift. It then is parted in two by Goat Island, the narrow part dashing down by furious rapids to the American Fall, which is a straight curtain of water shooting down a perpendicular height of 160 feet. The wider branch makes a turn round Goat Island and is very wide, and the breakers dance merrily in the sunshine, until the waters concentrate themselves at the Horse-shoe or Canadian, Fall—the greatest volume of water being at the V-shaped apex in the centre, where the depths of water at the lip is sufficient to impart a brilliant emerald color to the water. From the Falls downward for many miles the river runs through a precipitous gorge. For the first mile it is sluggish, but with gurgling upheavals of the water from below. Then come the terrible whirlpool rapids where Captain Webb was drowned. After that a sulky repentant river creeps to Lake Ontario.

There are three things at the Falls themselves which rivet the attention. 1. The water takes four or five seconds to fall, and in doing so it assumes the most fantastic forms of drapery. 2. The mist and spray rising from the base of either Fall is drifted by the wind, or in a calm rises in a cloud 1000 feet in height. 3. The third feature is the noise. You have not only the rushing noise of the Rapids, but also a booming, at times resembling a thunderclap, when the somewhat intermittent flow tumbles upon the water beneath, and shakes the foundations of houses half a mile away. The village or town of Niagara Falls on the American side of the river is built of wood. It is dirty, and the streets are bad. Its industry is the catering to excursionists. Cheap restaurants, merry-go-rounds, itinerant photographers, and museums of Indian and other curiosities are the chief features. The last are mostly impostures, always excepting the world-famed "Katie & Libby's Stores," where genuine curios are to be found, and many pleasing souvenirs. This village is remarkably conducive to the concoction of lies, and the Falls lend themselves to the art. The prophets of this cult are the hackmen (cab-drivers), who earn the gratitude of the excursionist by the thrill of their narratives. I believe, however, I have reliable evidence for some remarkable statements. 1. On the 1st of April 1848 the Falls ran nearly dry owing to a stoppage by ice and a strong east wind on the lakes. 2. A drifting ship, drawing sixteen feet of water, went over the deepest part of the lip of the Horse-shoe Fall. 3. A steamer called the Maid of the Mist, built at the Falls, traversed the Whirlpool Rapids in order to escape creditors, and reached Lake Ontario in safety. I cannot, however, vouch for the generally-accepted statement that in doing so she turned a complete somersault. 4. At the Whirlpool there is a path descending to the water to a spot where they catch the bodies that float there. There is an average of one suicide a month, and they are invariably trapped by the Whirlpool. 5. There is another true story which is rather startling. A hundred yards above the brink of the American Fall a rock ten feet square projects for a foot above the water in mid-stream. One morning the inhabitants awoke and saw a man sitting on it. The noise of the Rapids prevented verbal communication. They did not, do not, and never will know how he got there. He stayed there thirty-six hours. The people telegraphed to Buffalo, and the railway company sent one excursion train after another for thirty-

six hours to see the man on the rock. They painted signs and stuck them up for the man to read, saying, "We will save you." Two hundred yards above there is a bridge. From this, by ropes, they floated rafts with provisions to him. At the end of his stay a big one came for him to get on. What they were going to do with him if they got him in this seething rapid I know not. He tried and failed, and went over the Fall, and that is all!

People are differently affected by their first sight of the Falls. Some say, "How disappointing!" others, "How magnificent!" Some (Colonel Bob Ingersoll was the first to say this to me, but I have heard the same from others), "How horrible!" and others say, "How seductive! I want to go over with the water."

The Falls in winter are totally different from what they are in summer. Every bush and tree is a work in silver filigree. The precipices are concealed behind icicles 60 feet long. Every rock in the river is the nucleus for a dome of frozen spray rising 150 feet it may be.

When you know the river you will love it; but to know it you must see it at every season and at every hour—at sunrise, noon, and by moonlight; in sunshine and storm; with the mist rising as a tower, or drifting away to unveil new points of beauty. You must know every corner, peaceful or violent; you must see it from above and from below, and from every point of view, and always you will hear that thundering boom that shakes the ground. It is best to live on the Canadian side at the Clifton House, open only in summer. The most impressive points of view are those that make you feel the smallest. Mr. Bayard, the United States Ambassador in London, tells me that the only true way to appreciate the grandeur is in the early morning to swim across from the Canadian to the American side, just below the Falls. He has often done it, so he ought to know.

To me the great charm of the Falls is their immutability and change. The drifting spray and varying light give the changes of a kaleidoscope, but the volume of water pouring over never varies. They remind me of the face of a dear friend, always the same but never two moments alike. I suppose there is nothing to compare with them in size or grandeur except the Victoria Falls of the Zambesi; and Livingstone, who never exaggerated, said that these were the finer.

The "utilization of Niagara" is a hateful phrase to the lover of nature. But it must be stated at the outset that what is being done does not in the least degree affect its beauty. Only a small fraction of the water is to be used, and all the works are more than a mile above the Falls.

It is time now to leave the digressions about the beauties of Niagara to explain how it is possible to make use of this power without affecting the scenery. Now "gentle reader," do not for a moment imagine that I am going to burden you with engineering details in any part of this article. I hope to allude to them only in such a manner as to excite your interest rather than to bore you. Any one who has visited the Falls of late years knows that the land on the two sides has been appropriated by the United States and Canada respectively for national parks. The old mills which used to be in the stream above the American Fall have been removed for æsthetic purposes, and the land laid out with some attempt at good taste. On the Canadian side the same thing was done, but I regret to say that the rapacity of the Legislature of Ontario has not proved equal to withstanding the blandishments of the greedy capitalist. Two lines of rails traverse the whole of the National Park at the edge of the gorge. After the land had been confiscated by the Government, and the owners had been paid only a fraction of its true value, it is now turned into a source of revenue by the Government, and a gold mine to the capitalists, at the expense of the visitors, who can no longer enjoy the peaceful quiet which Lord Dufferin tried so hard to give them.

In spite of all that the Americans have done for preserving the beauty of the Falls, there is one terrible eyesore—a large number of mills have been erected at the edge of the precipice over the gorge. To these the water

of the upper river has been led by a canal passing through the town. This water drives water-wheels or turbines in the mills, and is then shot over as waste water down the precipice. Not only is this hideous in itself, but it is repulsive to the engineer, because of the great waste. They use only a few feet of the fall, and waste over 100 feet.

Thirty years ago an American engineer of the name of Evershed proposed a plan by which the mills should not be in view of the Falls, and by which the power might be utilized without detracting from their appearance, and the fundamental idea of this plan has now been actually executed. Mr. Evershed's idea was to take in the water from the river by a long canal a mile or two above the Falls. Along the banks of the canal mills were to be placed requiring power. At each mill a hole or shaft was to be dug in the ground to a depth of about 150 feet. The bottoms of these shafts were to be all connected by a long tunnel passing from them under the town at a gradual slope and emerging at a tunnel mouth below the Falls, on a level with the lower river. At each mill-site a water-wheel or turbine was to be placed at the bottom of the pit, which would rotate a vertical steel shaft coming to the surface. At the top this shaft would, by means of cog-wheels or belts, turn the machinery of the mill. In this way the canal was to bring water to the pit, and, having given up its power to the water-wheels, was to flow away by the tunnel into the lower river. Such a tunnel has been built, though the details of Mr. Evershed's plan have been altered. The result is that the factories and mills are far distant from the Falls, and do not interfere with the views. The tunnel has been built so as to be capable of using 100,000 horse-power or more. There are not many manufacturing towns in the world whose steam-engines all combined would give so enormous an amount of power as this. As Dominie Sampson would say, "It is prodigious!" The tunnel-mouth can be seen from the Canadian side of the river, and looks like a mere speck compared with the volume of water which is pouring over the Falls. A single glance is sufficient to convince anybody that even when 100,000 horse-power, or many times that, has been used, the effect will be imperceptible. But even now the water which is being used issues from the mouth with great velocity, and sets up quite a strong current across the surface of the stream.

Probably every engineer who ever visited this spot has been struck with the vast amount of power going to waste. But I am very doubtful whether its use could have been a commercial success before the electrical art had been so much developed that it was possible to distribute power by its means for all kinds of purposes.

Nevertheless, before this question had been entered upon, some New York capitalists were found who were prepared to take the matter in hand. At that date such an action was a bold stroke; but fortune in this case favored the bold, and the electrical work which I have carried out has been done at a cost which even now seems incredible to many.

In 1889 the Niagara Falls Power Company was formed to carry out this work, and their first act was to buy up all the land in the neighborhood. The capital subscribed was wholly American, and amounted to £2,000,000, about one-half of which has been spent. The acting committee consisted of railway men and lawyers. The chairman, as usual, is called a president. They like giving big names to things in America. A pond is a lake, and a hill is a mountain; they never speak of the sea, it must be called the ocean; a meeting is a convention, a dictionary is a "speller and a definer," a town is a city, a chairman is a president, and so on. The only exception I know of is that the wealthy people who own those charming country residences at Tuxedo and Lennox call them cottages. But these are not average Americans, and in that country the manners and customs, as seen by the ordinary traveller, are governed by the average man, who is not a good specimen. He is apt to be a most awful "bounder," has no taste, and does not know the meaning of the word "repose;" but you need never meet this type except in railway trains and hotels. His ideal, as one

of them told me, is to spend his nights "on the cars" and his days in getting the better of his fellow-men. But the refined American is quite different. These are mostly met in Washington and the south, and, of course, Boston is a thing apart; and as you approach this town you are told that the humming you hear is the noise of people reading Browning. Tuxedo also is a great exception, where you can have congenial society. It is a large estate with woods and lakes and forty miles of well-laid roads. Country houses or cottages have been built all over it, and there is an excellent residential club—into which, however, the female element has progressed so far as to have introduced even babies into the bedrooms!

I must really ask to be excused for such digressions, but I must tell my story in my own way or leave it alone. The chairman of the company which has utilized the Falls is Mr. E. D. Adams, well known as a banker and a reorganizer of railways. The first vice-president is Mr. F. L. Stetson, a lawyer who has also had much experience in the finance of railway companies. Mr. Cleveland, the U.S.A. President, is a partner in his law business. The second vice-president is Mr. E. A. Wickes, also a railway-man. The secretary and treasurer, Mr. W. B. Rankin, is one of the most able and energetic and charming men I met in the States. I only hope he will not utterly ruin his health by overwork. All these are very able business men, though not engineers, and the affairs of the company could hardly be in better hands.

In October 1889 the Niagara Falls Power Company was formed to carry out the great work of utilizing the Niagara Falls on so gigantic a scale that all previous attempts to use water-power at once sank into insignificance. The Cataract Construction Company was at the same time formed by the same people to carry out the work. All that they had then settled was that they would make the tunnel proposed by Evershed for carrying away the used water. They had not settled whether the mills should be brought to the power, or the power to the mills. They had no estimates of the cost. If power were to be distributed to mills and factories, they had no notion whether it would be by means of air or water under pressure in pipes, or by wire ropes, or by electricity. None of the acting committee were engineers, but they had faith in the evolution of ideas which would culminate in success.

In order to obtain more definite ideas they invited certain engineers to prepare plans of any methods they might think best. These were to be laid before a Commission of engineers and physicists from England, France, Switzerland, and America, with Lord Kelvin as chairman.

At first I declined this invitation on the grounds that the method of competition is contrary to my professional practice, and also that with so novel a problem I would not accept any man, or combination of men, to adjudicate upon the project which I might decide upon.

Having learnt, however, accidentally, that any electrical plans to be submitted would not be of a satisfactory nature, I withdrew my refusal in order that a plan, as I conceived on proper lines, might be at least in evidence.

Up to this date there had been only one example of electric-power distribution, and that was in a small village called Oyonnaz, on the frontiers of France and Switzerland. But the problem now before me was entirely new in many ways, besides being of gigantic proportions. The object was to send *power* rather than *light* over the wires. But I found that every different user of the power would want his electricity delivered at a different pressure (it is not here necessary to understand the meaning of the words "electric pressure"). House-lighting, street-lighting, electric tramways, flour-mills, metallurgical processes, all required different "pressures." Also, if we were to carry any of this power through wires to a distance, "the pressure" must (for sake of economy) be very high during transit, and be reduced at the place where it is used.

Now let me say, without explanations, that there are two kinds of electric current—a "continuous current," always flowing in the same direction, and an "alternating current," in

which the direction of flow is reversed, it may be hundreds of times in a second.

I soon realized the fact that not only could the latter current be more easily obtained at high pressures, but that it could easily, and without moving machinery, be transformed to any required pressure at any spot when it was wanted.

Up to that date, 1890, both kinds of electric current had been used for electric lighting, but the alternating current had never been used for giving mechanical power except in an experimental way. For this reason it seemed to most people absurd to suggest its use for Niagara Falls. I would have shared this view were it not that for several years I had visited the United States and the continent of Europe to study the progress that others were making in electric work. I had thus become well acquainted with the system which Nicola Tesla, a young Montenegran, was experimenting on at Pittsburg, U.S.A., called a "two-phase" system. He distributes two alternating currents, one of which attains its maximum when the other is at its zero value. With these two currents a simple form of motor could be worked to supply power to shops, factories, or mills. I also had seen many things in various parts of Europe not generally known in England. Owing to these varied experiences, I had an opportunity above all others at that date of foreseeing that the alternating current would soon be very generally applied not only to light, but also to motive power.

Acting upon this knowledge, I worked out complete plans, using only machinery which could then be got in the open market, and was able to furnish complete working plans, drawings, specifications, and estimates of cost. This laborious work when concluded left no doubt in my mind that the alternating current must be adopted.

The Commission sat upon these plans, and, as I expected, denounced the alternating current, for none of them had had the experience which I possessed of the latest developments. How well I remember walking along Piccadilly with a member of the Commission. He told me of this decision with an air of sympathy with my supposed misfortune. He was somewhat surprised when I replied that nothing could have given me greater satisfaction than this decided expression of opinion, "for," I said, "the alternating current will certainly be adopted at Niagara."

I heard no more from the promoters of this enterprise for over a year. It took them all this time to realize that the Commission had made a mistake. Lord Kelvin was the most violent opponent of the alternating current; and for long afterward (although he is my most esteemed and oldest scientific friend), even when I was appointed as the consulting engineer, he continued to write and cable to the company, though his opinion on this point was not asked for, telling them that they were making a "fatal mistake" if they followed my advice. His latest expression of opinion in this sense was in November 1894, when my work was practically completed. Such a line of action has hitherto been unknown among professional men. I need hardly say that this opposition on the part of so eminent a man was a stumbling-block which might well have wrecked the whole scheme; but in this and other points where my plans were at variance with the opinions of others, I was most loyally supported by the directors, and through this support alone they and I have been enabled to put the works into their present satisfactory condition.

To add to the difficulty, the highest scientific authority in the States had taken up the same position as Lord Kelvin. Fortunately, however, the year 1891 saw some great developments in the use of alternating currents for motive power in Europe over a distance of 112 miles, and our American opponent frankly confessed to a change of opinion owing to the results then attained.

Early in the year 1892 it became evident to the acting committee that the views of engineers had been undergoing a change, and that the use of alternating currents for Niagara was a neces sity, thus indorsing the prophecy I had made long before. They then asked

me to act as their electrical consulting engineer, and during that year and the next and the next I was almost constantly in the States. The only real rest I ever got was in my voyages across the Atlantic. I soon came to feel at home on all the large liners. The Campania, Lucania, Umbria, Etruria, Majestic, Teutonic, and many others were havens of rest; and one always feels glad to meet old friends in Captains M'Micken (now, alas! dead), Haines, Parcell, Walker, M'Kay, Murray, and many others. The misfortune is that at most seasons the only class who travel much are American bagmen, or drummers, and they are not a favorable class to judge Americans by.

Sometimes I lived in New York, where the offices were; sometimes at Niagara, to be near the works. I did not care to go much into society, but I made some very firm friends, specially the Hewitts, and our amiable Consul-General Sir William Booker and his charming American wife. My greatest friend of former days had been S. L. M. Barlow, a well-known and remarkable man. Roscoe Conkling and I used to dine with him every Sunday. These two lawyers, both able men, on opposite sides in politics, and also in the great Stewart will case, amused and instructed me much by the exposition of their views on men and things. Both were dead now, and I had two friends the less to help me to pass these three years. Part of the time I lived at Tuxedo, an hour from New York, where you could have fishing, shooting, boating, bathing, and golf; and I shall never forget the cordial welcome I there received from the Potters, Bruzes, Lorillards, Delafields, Fishes, Kents, Rushmores, Prestons, Van Courtlandts, Van Nests, and from Allen Lathrop and many others. The lovely scenery and genial society of this place helped me greatly to retain health during a period of anxious and arduous work.

Now I must go on to describe what has been accomplished. The tunnel of which I spoke is 21 feet high and 19 feet broad, and is horse-shoe-shaped. It was expected that no lining would be necessary, but at the outset the roof began to fall in, and it had to be lined with four courses of bricks, increasing the cost largely and diminishing the capacity from 120,000 to 100,000 horse-power. The tunnel is 7000 feet long, mostly on a slope of 7 feet in 1000 feet. At the mouth there is a curved surface of iron for the water to flow over smoothly. The level of the water below the Falls varies a good deal. Sometimes it is far below the tunnel-mouth, at other times it is several feet above.

The plan of having a separate shaft for a mill has been adopted in only one case, the largest paper-mill in the country, where at present 3300 horse-power is being used. The paper is made out of wood-pulp, and trunks of trees have to be ground down for this purpose. This accounts for the large amount of power used.

It is intended to supply all the rest of the power from a great power-house where electricity is generated. Within this building a slot in the ground, communicating with the tunnel, has been excavated to a depth of 150 feet. It is 20 feet wide and some 150 feet long. Parallel with this slot there is a canal of great width taking in water from the river. From the canal to the slot there are water-passages from which iron pipes 7½ feet diameter descend to the bottom of the slot. At the bottom of these the water passes into the casing of the turbines, and in passing through these develops power to the extent of 5000 horse-power for each unit. Three of these are in place. The power is given to a vertical shaft 2½ feet in diameter except at the three bearings, where it is less. This steel shaft extends right up to the surface of the ground, and is attached at the top to the revolving part of the dynamo, which generates the electric current. Two designs of these turbines or water-wheels had been received from Swiss makers, and the selection of the best was intrusted to another English engineer, Professor W. C. Unwin. The company has, besides its powers on the American side, acquired a control of the rights on the Canadian side, rendering the undertaking international in its character, and also in the benefits to be conferred. In the autumn

of 1892 Professor Unwin accompanied me to the Falls, and he then made a study for the company of the hydraulic work to be done on the Canadian side. So that English engineering has been represented in more than one part of this great work.

In 1892, when I came to examine the plans put in by various manufacturers, I found that some of the crudest work conceivable had been submitted by the Americans. The Europeans sent some excellent designs, especially the Oerlikon Fabrik, near Zurich. But these makers were handicapped by the duty imposed on machinery imported into America. There was, however, one fatal defect in all the plans then or subsequently submitted by the manufacturers. I must explain that all the revolving parts of turbine, shaft, and dynamo have their weight supported by a hydraulic piston in the turbine—being balanced, in fact, by the water-pressure. The total weight which could be supported was thus strictly limited. Also, the designers of the turbines (Messrs. Faesch & Picard of Geneva) required that there should be a certain momentum or fly-wheel effect to assist the regulation of speed. In none of the designs submitted had the revolving part of the dynamo sufficient fly-wheel effect. In every case it was necessary to add a large heavy fly-wheel ; and in every case this increased the weight beyond what was permissible. The American manufacturers were entreated to alter their dynamo designs to meet this difficulty. They tried, but they were unable to do so. We were then in a most awkward dilemma, and it looked as if a serious departure from the original design of turbines must be made. Meanwhile I had been constantly working at various new designs, and at this stage I saw that, for the credit of the company, it was imperative that I should, if possible, get out a design on new lines which should have the required fly-wheel effect without too great a weight. A dynamo always consists of two main parts, a fixed and a revolving part. In every one of the many designs sent in the revolving part was central—*i.e.*, inside of the fixed part. It occurred to me that if I could make the external part revolve I should get a maximum of fly-wheel effect with a minimum of weight. By making the external part bell-shaped, I was able to attach the centre or top of the bell to the top of the vertical shaft, and the central fixed part resting on the floor could be reached from below. I proceeded to get out rough designs, and found, with the utmost satisfaction, that I could meet all the requirements of the turbine-makers. I also found that this design gave far greater mechanical strength to the revolving part of the dynamo—an important matter, with this forty tons revolving more than four times a second. Further, the magnetic attractions which in all the other designs increased the dangers from centrifugal force, in my design actually diminished them. It soon became evident that this happy idea of revolving the external parts completely extricated the company from the very awkward dilemma in which they had been placed. I then proceeded with a large staff of draughtsmen to get out the working drawings, and I secured an American patent as a protection to myself and my company. It was a matter of considerable satisfaction to all concerned that I had thus so simply got over the serious difficulty which at one time threatened us with starting afresh on all the machinery, turbines and all. We were now able to feel quite easy about the hydraulic and electric generating plant. The only weak part in the scheme seemed to me to be the vertical steel shaft. The officials, however, were satisfied, as it had been passed by the Swiss firm who designed the turbines (though made in Philadelphia). I had always wished to put the dynamos at the bottom of the pit close to the turbines, and I still believe that this arrangement would have served us better.

The designing of a suitable dynamo was, however, only one of a number of difficulties that had to be overcome. Some of these were of an engineering character, but others savored of "politics" in the sense in which that word is used in the States. There *politics* means intriguing, underhand dealing, and jobbery, and is always used in conversation to express that meaning.

Until I went to America the manufacturers of electrical machinery never had a consulting engineer to reckon with, but dealt directly with the financiers, who knew nothing about cost or efficiency of machinery. When they knew that I was to advise the Niagara Company, they tried by every means in their power to revert to the old plan. Every game of bluff, bounce, and threats was used, but without the least effect. One of our engineers, in another department to mine, who knew nothing of electricity, was completely taken in by one of these firms. This and other intrigues hindered me a good deal in carrying out my plans. Then, again, I had at times great difficulty in keeping the president and vice-presidents in hand. One of the latter, after he had learnt a little about ohms and volts, believed himself capable of instructing me as to which tenders I ought to recommend for acceptance, and did his best to try to influence my judgment. Most of them began to think they knew something about the subject, and that they were quite capable of settling what tests the machines should be put to. All this was generally amusing enough, but became almost tragic at times when I found them endangering the whole work. On such occasions I would write to my millionaires and tell them that if they did not do what I told them they would be personally answerable to the directors and shareholders for any disaster that might occur. This always had the desired effect, and my point was carried. I fear that at times they wished me at Jericho, but after any one of these tiffs was over I think they were glad that I had taken that line.

I have said that there were many new electrical problems to attack. One of these was a new departure on my part, which involved a very heavy piece of calculating and designing before I could be perfectly certain that my conclusions were correct. It occurred to me that with the large machinery we were using (the dynamos which I designed were three or four times as powerful as any that had then been made) it would be best to make the alternating current reverse its direction as slowly as was consistent with making a good dynamo. This would not do so well for *lighting*, but for a *power* station like ours the advantages were powerful and numerous. The one objection that struck me was that the machines used for changing the electric pressure would be more expensive. This compelled me to design all these machines (they are called transformers), and to calculate the cost of construction. I was then agreeably surprised to find that the cost was enormously less than any one had dreamt of. At the same time, out of every 100 horse-power put into such a transformer we could get out 98½ horse-power, a result which had never been approached in smaller machines. Then, again, some of the manufacturers threatened us with patent-litigation if we used certain types of machinery, so I had to get out designs of another kind of motor to drive the mills, so that in any eventuality we should be prepared and able to go on in spite of these threats. Then our first customers wanted continuous current, and I had to select a method of making the conversion. In fact, I found myself obliged, before we advanced a step, to have all the designs ready for manufacturing all kinds of machinery, even if they were not all to be used. This work, carried out under all kinds of difficulties put in my way, was chiefly done in the summer of 1893 at the Falls. I had a lovely house in park-like grounds (as the agents say) on the banks of the placid river above the upper rapids. I went to bed early and rose at five or six in the morning, and I shall never forget the delights of these glorious summer mornings at one of the most beautiful sites in the whole neighborhood. In the afternoons I generally took a drive in a buggy on the Canadian side, where the roads were passable, and sometimes I rode. I had a nigger servant to look after the house, who differed from all his race I ever saw in his desire for work. If I did not want the gravel rolled or the grass cut, he grumbled. He always got up at five o'clock, and prepared my bath. I used to ask Jim about his previous life, and found he had been "porter" on a railway, and latterly servant in a gambling-hell in Buffalo!

He was a good servant. This house belonged to one of the Porter family, who have long owned most of the property here. A Miss Porter was once travelling in Europe, and at the *table d'hôte* her neighbor said, "Oh, if you are an American I suppose you have seen Niagara Falls?" She turned to her inquirer, and fixing him with her eyes, she said, "I own them!"

An Englishman in America should always try to retain his Englishness,—otherwise in a year or two he will be reduced to the level of an average American. Where all men think themselves equal, individuality is at a premium. An American once tried to find fault with me for pitching into my servant, because, forsooth, all men were equal. I never saw the man before, and would never see him again. So I told him that if he wished to be placed on a par with my valet I would willingly acquiesce, but he must not attempt to define my place on so short an acquaintance.

I acquired quite a reputation on the New York Central Railway from a little Englishman. I had forgotten all about it when a friend at the Falls, arriving home from New York, said he had heard of me. "How is that?" I asked in the vernacular. "Well," he said, "you seem to be able to get the better of the conductors on our railways" (the most insolent class of men in the country). "I was talking to one on the cars, and when he heard I belonged to Niagara Falls he said, 'Oh then, you know Professor Forbes.' I said I did, and he said, 'Well, there's no flies on him.' I asked him why, and he said, 'One night we were coming from New York, and in the early morning six of us conductors were in the smoking-room yarning when in comes Professor Forbes: he takes a look round and then says, "I want to smoke, but pray don't disturb yourselves, I am only a passenger;" and we all put our tails between our legs and slunk out, and then we roared with laughing to think how he had got the better of us in his quiet way.'"

These were very happy days, though I lived quite a solitary life. Of course I had anxieties and worries, but I felt quite certain of loyal support in any case where the safety of the work was threatened.

The dynamos were at last made and tested, after most annoying delays and disingenuousness on the part of the manufacturer. The makers of the transformers and machinery for getting a continuous current, on the other hand, were prompt and obliging, and the tests came out well. Then I got bids for the appliances for transmitting power to Buffalo. All the conclusions I had arrived at from my own designs were now confirmed. Their cost per horse-power, even with my low frequency, was a fifth part of those that had been used for lighting, and the efficiency guaranteed was as I had stated. I decided on all this transmission plant, and it is not now put in only because the Buffalo people want to get the power for next to nothing. There is too much "politics" in this business at Buffalo. Another triumph I have had is, that engineers all over the world have learned to appreciate my low frequency of alternations, while we ourselves have found new merits in it at every step.

I had also arranged for special apparatus for people who had set up a factory within a mile of the power-house, and who wanted 1000 horse-power, and wished to be able to vary the electric pressure during the heating of their electric furnace. Arrangements for arc lighting, for tramways and house-lighting, had also to be arranged. When this was all completed and the first plant in place, the period of construction and design gave way to a period of dividend-earning, and my continuing to take charge would have swallowed up too much of the annual income, so I concluded my engagement with the company. In writing my farewell letter, I felt how much I had been assisted by the acting directors, and I told them so while summarizing the results which we had been enabled to attain to. In this letter I said that we now had completed a work which for successful working, security against break-downs, high efficiency, and low coast, was ahead of anything that had hitherto been even dreamt of, and that I was confident of a great success from a commercial point of view.

The company, through their president, replied in cordial terms as to the satisfactory results of our co-operation, from which it may be interesting to make the following extract :—

"In our desire to secure the best theoretical results under your eminent and valuable advice, it has been most gratifying to have had your cordial co-operation up to this point, where the commercial manufacturers are ready to give us satisfactory guarantees of performance.

"When you were selected as the electrical consulting engineer of this company, we recognized that the novelty in the proposed size of units to be used in the Niagara installation, and in the character of the station proposed for the generation and distribution of power, was such that we must have the benefit of the very highest scientific advice. We further recognized that in the advocacy of the use of the alternating current and of low frequencies you were a pioneer, and we join you in the feeling of just satisfaction in the conclusion which has now been reached in respect of those features. In this, too, your independence of thought and action has been of peculiar service, while, through your original design of the stationary armature and revolving [external] field of the generators, adopted by us, you have relieved us of one most embarrassing question in connection with the relation of the generator to the turbine. Nor can we fail to recognize the value of the vast fund of information which you have brought to us concerning electrical installations in different parts of the world, and well described in your various and exhaustive reports.

"In making you this partial expression of our appreciation of your assistance during your professional connection with this company, we beg to assure you that we now part from you with the best wishes for your professional and personal success."

The letter from which I have made this extract attributes the splendid results which we attained mainly to engineering skill. I am inclined to believe that they were fully as much the result of an exercise of tact, judgment, and forbearance, combined with firmness—qualities which I do not hesitate to say that both the officers of the company and myself recognized in each other, and without which we should have found it difficult to obtain satisfaction from the manufacturers. We had the utmost difficulty in enforcing proper tests for balance of the dynamos, and the strict rule that no circuit should be suddenly opened or closed while carrying a large current. I mention these as being two matters of prime importance, the neglect of which would have been a crime. Owing to the support I obtained from the acting directors, the whole work for which I was responsible has been put in place and set agoing without a single hitch. This is not usual in a novel work of so great magnitude. I feel confidence in asserting that so long as the instructions I insisted upon are acted on, there will be no trouble with the electrical machinery.

In jotting down these personal experiences, I may have failed to give a *coup d'œil* of the whole scheme. Now there is at the Falls a small tower of observation, like Eiffel's, 300 feet high. The last time I was there I penned a letter to the "Times," which was published at the end of the year 1894, from which I may make an extract : –

"I am perched on the top of a small Eiffel tower, lately erected, and casting my eyes up the river, over the house-tops and beyond the town, I see a new world created. There is a wide canal leading water from the river into that gigantic tower-house where three turbines are set up to drive three dynamos of 5000 horse-power each. There is the bridge to carry cables across to the transformer house. Inside the tower-house the water is carried down pipes 7½ feet diameter into the turbines, and thence it passes through a 7000-feet tunnel under the town, emerging below the Falls, the tunnel being capable of developing 100,000 horse-power. Far as the eye can reach extend the company's lands, with here and there a huge factory either now using the water-power, or waiting for the electric supply. One of them uses 3300 horse-power, another 300, a third one 1500, and that unfinished one requires 1000. You can see, far away, the model village for working men, and improved sewage-works with drainage, pumps for water-supply, electric light, and well-paved streets. There again is the dock where ships from all parts of the Great Lakes can unload, and there a huge expanse of reclaimed land ; while the whole is swept by the company's railway, seven miles long, connecting every factory with the great trunk lines."

Since these words were written the

machinery has been set to work on its commercial task of supplying power and earning money.

The directors have no present desire to send the current to great distances. It will pay better to create a smokeless manufacturing town in the neighborhood. If required, the power could be sent much more than a hundred miles, and still be more economical than steam, even though coal is cheap there. In countries where power is much wanted, but very costly, the electrical transmission will be successful at distances of many hundreds of miles. Such cases occur in many places where there are valuable mines but no fuel.

In conclusion, I may say that the work done at Niagara is the forerunner of much more, and already I have in hand the preparation of plans of schemes nearly as important.

I also wish to bear tribute to the kindly friendship which I almost universally experienced at the hands of American engineers. Hardly a single case occurred where any jealousy was shown at an Englishman (or rather Scotchman) being selected to carry out the work.—*Blackwood's Magazine.*

THE PRESENT CONDITION OF RUSSIA.

BY PRINCE KROPOTKIN.

THERE is not the slightest doubt that the feeling which now dominates in Russia is the need of a deep, thorough, and sincere revision of all the most fundamental conditions of existence of the nation. The best men of Russia, in all classes and strata, are convinced by this time that it is no longer possible to persevere in the direction which national life has followed for a time ; that to do this would mean to throw all further development on a false track ; to paralyze the best energies, to vitiate national character itself, and to prepare national catastrophes, unfathomable as to their ultimate results ; that an effort must be made to get out of the old grooves and to find the way to open a new phase of development.

All nations have known such periods. Western Europe, too, is feeling at this moment the need of a fundamental revision of the bases of its economical life. But nowhere is this need felt so acutely as it is in Russia. No other nation of Europe has ever had to face such national calamities as the famine years of 1891 and 1892, and to convince itself of its utter helplessness to prevent like calamities in the future ; no nation has undergone such a systematic annihilation of all its organs of local self-government, and such an obstruction of all the channels in which the local constructive forces could find an issue from the present difficulties ; and none has seen such formidable weapons of repression, so obstinately applied for a succession of five-and-twenty years, to prevent the best forces from becoming active factors in national life. Nowhere else do the problems at issue involve so deeply the very first conditions, economical and political, required for the life of a nation.

The feeling I speak of is not of yesterday's birth. It dates from the famine of 1891, when thousands of men and women were brought face to face with the undescribable misery of the peasants,* and could ascertain on the spot how the best energies of private men, and the endeavors of what then remained of local self-government, were paralyzed by the functionaries, who treated every effort going beyond mere charity as an encroachment upon their own spheres of activity. Since that memorable year, optimism or indifference being no more possible, a decided revival of public opinion has begun to take place in Russia. The whole tone of the daily press, the review, the book of economic science, and even the novel has changed ; and

* More than twenty years ago an Imperial Commission concluded its report upon the state of the peasants by these words : "The peasantry is now in such a state, that a slight failure of crops will unavoidably result in a terrible famine." The prediction was only too just.